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EDITORIAL COMMENT

The Fish Mouth and Three-Dimensional Echocardiography: New Technology Catches an Old Problem*

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Despite advances in antibiotic therapy aimed at preventing the valvular inflammation and distortion that is characteristic of rheumatic mitral valve disease, this condition continues to be a major health problem worldwide. For the past 25 years, echocardiography has played a crucial role in diagnosing the presence and severity of rheumatic valvular heart disease. With advances in interventional therapies, echocardiography has continued to play a pivotal role in assessing patients before and after interventions. Twenty-five years ago, Henry et al. (1) reported on the ability of the then-new field of two-dimensional echocardiography to planimeter the mitral valve orifice. The following years led to the development of Doppler echocardiography, which provided hemodynamic information about rheumatic heart disease; and in the last decade, transesophageal echocardiography (TEE) has played a key role in both selecting patients for, and evaluating patients during, percutaneous valvuloplasty.

Echocardiography is unique in that it allows both anatomic and hemodynamic assessment of the complex mitral valve apparatus. In addition, it provides anatomic and hemodynamic information about other associated valvular abnormalities, as well as direct information about the effects of the rheumatic process on cardiac chambers. Planimetry of the mitral orifice has been considered the noninvasive gold standard when determining the severity of mitral stenosis. This measurement is independent of hemodynamic variables, including left ventricular diastolic compliance.

Echocardiography is a technique that relies on accurate performance and interpretation for its proper utilization. Awareness of potential technical and interpretive pitfalls is central to its application in diagnosing known or suspected cardiovascular conditions. Over 20 years ago, my colleagues and I (2) highlighted the technical problems that could lead to errors in accurate planimetry of the mitral valve orifice. This fact, as well as the fact that transthoracic echocardiography (TTE) provided adequate visualization of the mitral valve orifice in only three-fourths of the patients with known rheumatic mitral valve disease, led to the welcoming of the field of Doppler echocardiography as an additional noninvasive method for determining the severity of rheumatic mitral valve disease. Hatle et al. (3) introduced the concept of Doppler evaluation of mean mitral gradients and valve area by spectral Doppler echocardiography. Despite these advances, it must be remembered that both the Doppler technique and the catheterization technique provide only indirect measurements of the mitral valve orifice area, with the true cross-sectional area of the rheumatic mitral valve being the gold standard for quantitating the severity of mitral stenosis.

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In this issue of the *Journal,* Binder et al. (4) introduced the concept of real-time volumetric echocardiography (RTVT) to the evaluation and understanding of the rheumatic mitral valve. This technique utilizes a matrix-array echocardiographic probe that provides instantaneous acquisition of a data set within a pyramidal volume. The dramatic aspect is that this data set is obtained in one cardiac cycle, which makes possible the reconstruction of any two-dimensional echocardiographic plane from a single volumetric set that is independent of the echocardiographic "window" from which the data were acquired. Real-time volumetric echocardiography provides two intersecting orthagonal long-axis scans in a B plane, with a perpendicular short-axis C-scan line that can be angled at 1° and moved up and down in the pyramidal volume in 1.0-mm slices. The ability to provide multiple two-dimensional echocardiographic planes in any image orientation is a unique advantage of this technology.

Binder et al. (4) compared this technique with standard TTE (including Doppler) in 48 patients with known mitral valve stenosis. The authors found that RTVT was extremely accurate, especially when taking into account interobserver variability. Also of note is that this technology allowed for rapid assessment of the severity of mitral stenosis by allowing complete acquisition of data and analysis in less than 5 min per patient. Finally, the authors highlight the difficulties encountered by standard TTE, whereas minor alterations in image plane and short-axis views of the mitral orifice can lead to major overestimations of the mitral valve orifice size. The authors point out that RTVT improves both performance time and accuracy in evaluating patients with mitral stenosis, both of which are important advances in today's outcome-oriented health care environment.

Binder et al. (4) obtained good echocardiographic images in all 48 patients scanned by RTVT, whereas standard TTE provided adequate images for planimetry in only 89% of patients. The fact that this technique may provide excellent images for evaluating the mitral valve orifice in all (or nearly all) patients would be a major advance in the noninvasive

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assessment of rheumatic mitral valve stenosis. Binder et al. also point out how minor changes in the depth or angle of interrogation of the standard transthoracic ultrasound beam can lead to overestimation of the mitral valve area by anywhere from 63% to 83%—information that should be instructive for all those performing routine TTE for patients with known or suspected mitral valve stenosis.

In the mid 1980s, Inoue et al. (5) introduced the concept of percutaneous balloon valvuloplasty—a tremendous advance in the treatment of rheumatic mitral stenosis. Echocardiography has played a crucial role in patient selection because selection is tied not only to the degree of mitral orifice stenosis but also to variables such as leaflet mobility, leaflet thickening, degree of calcification of the leaflets and the presence or absence of left atrial and left atrial appendage thrombus. Real-time volumetric three-dimensional echocardiography appears to provide accurate information, not only about mitral valve orifice area but also about the morphology of the mitral valve and its subvalvular apparatus. Therefore, this technique should play a central role in aiding with patient selection for balloon valvuloplasty, as well as in the evaluation of the outcome of using the technique, once it has been performed.

What are the limitations of the current study? The authors did not have an anatomic gold standard (i.e., true pathologic inspection of the valve, either at operation or postmortem). Also, the authors offered no correlation with catheter-based data (Gorland formula), even though the limitations of the latter are well recognized. Most worrisome is the fact that the authors did not assess the accuracy of RTVT in the seven patients who had undergone previous mitral interventions (three with surgical valvulotomy and four with percutaneous balloon valvuloplasty). Because it is likely that these valves had undergone further distortion, it would be important to know whether RTVT had more difficulty assessing the mitral valve orifice in these patients versus the 41 patients who had not undergone previous interventions.

This is not the first time that three-dimensional evaluation of the mitral orifice has been attempted by echocardiographic techniques. Others have coupled TEE with computer reconstruction to provide three-dimensional images of the mitral valve orifice (6). The obvious advantage of RTVT is that it allows for rapid acquisition and analysis of the data (not relying on time-consuming computer reconstruction), compared with the transthoracic approach. An obvious limitation, though, is that unlike TEE, it is unknown how much data this technique would provide about left atrial and left atrial appendage anatomy.

What does the future hold? Combining anatomic information provided by RTVT with Doppler color flow imaging information should allow for more accurate assessment of the presence and severity of both stenosis and regurgitation of not only the mitral, but also any other valvular structure. The ability of this technique to potentially offer color Doppler variables in a three-dimensional real-time method should allow important anatomic and functional information about volumetric flows across stenotic or regurgitant valves. Applying this technology to abnormalities of the aortic valve would be a further advance in the evaluation of patients with known or suspected significant aortic stenosis and regurgitation. Finally, coupling RTVT with the transesophageal approach would lead to advances in the diagnosis and management of various cardiovascular conditions, including thoracic aortic abnormalities.

What should we take away from this report? First, one needs to remember the complexity of the mitral apparatus and how the complete evaluation of its components is necessary to understand the pathophysiologic impact of a disease process, such as rheumatic mitral valve disease. Second, we must remember that rheumatic disease can involve, directly or indirectly, other valvular structures and other anatomic entities, such as the left atrial appendage. Therefore, noninvasive evaluation of rheumatic mitral valve disease involves much more than simply calculating the mitral valve orifice area. It is essential to obtain data on involvement of other valves, such as the tricuspid valve, as well as right-sided hemodynamic data and anatomic abnormalities, such as left atrial appendage thrombi. Any technology, especially any noninvasive technology, offers the echocardiographer the ability to fully ascertain the consequences of the disease process, so that appropriate management decisions can be made.

Right or wrong, we live in a world where speed counts. Volumetric three-dimensional echocardiography allows for the near-instantaneous acquisition of a complete three-dimensional data set from one acoustic window. Theoretically and realistically, RTVT should offer dramatic improvements in the speed of TTE. However, this speed should never come without accuracy. Accuracy, after all, is the gold standard on which all outcomes data will be based. At the very least, technological advances, like RTVT, allow for a better understanding of the limitations of current transthoracic technology. It appears that this technique may improve the accuracy of standard TTE for quantitating mitral valve stenosis. If RTVT technology can be applied both to real-time flow analysis and to TEE, dramatic improvements in noninvasive diagnosis will be possible.

Our goal in medicine is to always improve the care and outcome for a single patient. Reports such as Binder et al. (4) provide us with a glimpse into what advances in technology offer in our search for better care for the individual patient. By helping us to understand the limitations of current technology, this study should make all who incorporate echocardiography into their daily practice of cardiology better providers of care.

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